system applied to the magneto-optical recording medium as described above, in order to detect, upon reproduction, signals recorded as multi-valued signals, the multi-valued signals have been distinguished by slicing, at a plurality of levels, signals detected from the magneto-optical recording medium. Accordingly, it has been impossible to obtain a large difference in signal amplitude corresponding to each of multi-valued states, and it has been difficult to clearly distinguish two states with a close difference in signal amplitude therebetween. For this reason, a problem arises in that the S/N ratio is low with respect to reproduced multi-valued signals. Therefore, it has been demanded to realize a reproduction technique for obtaining reproduction signals at a high S/N ratio from a certain magneto-optical recording medium subjected to high density recording.

As for magneto-optical recording media each having a plurality of magnetic layers, a recording medium, in which information can be recorded and reproduced independently on each of magnetic layers, may serve as an extremely effective recording medium when various types of information are recorded on a single recording medium in a correlated manner, or when they are simultaneously recorded and reproduced in parallel together with a plurality pieces of channel information.

JP-A-4305841 discloses a method for reproducing a multilevel information which has been recorded by illuminating with a recording light a magneto-optical recording medium, which has a magneto-optical layer wherein a magnetization direction may be changed by means of a magnetic field and heat with the illumination of the light, and an enhanced layer wherein a refractive index with respect to a reproducing light may be changed depending on a heating condition with the illumination light, to independently vary the magnetization direction of the magneto-optical recording layer and the refractive index of the enhanced layer. In the method, the information is reproduced by illuminating the magneto-optical recording medium, onto which the multilevel information has been recorded, with two reproducing lights having different wavelength in order to independently detect the intensity of the respective lights. The enhanced layer must have a characteristic that the refractive index with respect to an illumination light used for reproduction is changed depending on a heating condition based on illumination of the light.

JP-A-7147027 discloses a method for reproducing a multilevel information from a magneto-optical recording medium having a first magnetic recording layer and a second magnetic recording layer by using two laser beams with length $\lambda 1$, $\lambda 2$. The magneto-optical recording medium needs

to use a spacer layer for transmitting the laser beam having the wavelength λ2 and reflecting the laser beam having the wavelength λ1.

Disclosure of Invention

The present invention has been made in order to solve the problems caused by the conventional techniques as described above, an object of which is to provide a novel method for recording and reproduction on a magneto-optical recording medium in which information recorded by multi-valued recording can be reproduced at a high S/N ratio.

Another object of the present invention is to provide a novel method for recording and reproduction on a magneto-optical recording medium having a plurality of magnetic layers in which data can be independently recorded (recorded in multi-layers) or reproduced on each of magnetic layers of the magneto-optical recording medium.

Still another object of the present invention is to provide a magneto-optical recording medium which is used for the method for recording and reproduction on the magneto-optical recording medium according to the present invention, on which reproduction signals can be reproduced at a high S/N ratio from the magneto-optical recording medium subjected to multi-valued recording.

Still another object of the present invention is to provide a novel magneto-optical recording medium which is

recording temperature (Curie temperature) by using a single laser beam so that the read information is recorded on the first magnetic layer again, and new information is recorded on the second magnetic layer subjected to rewriting. According to this method, apparently the information on the first magnetic layer remains as it is, and only information on the second magnetic layer is rewritten into the new information. Thus only one of the magnetic layers is subjected to rewriting.

Next, a specified method will be explained with reference to Figs. 9 and 10. The magneto-optical disk produced in the second embodiment was used as a recording medium. Accordingly, when the magneto-optical disk is operated in accordance with the reproduction method as explained in the aforementioned sixth embodiment, then information on the first magnetic layer can be reproduced by using the reproducing light beam having the wavelength λ_1 = 443 nm, and information on the second magnetic layer can be reproduced by using the reproducing light beam having the wavelength λ_2 = 780 nm on the recording medium. Two laser sources as shown in Fig. 9 were used upon recording of information, and two laser beams were collected so that they were deviated from each other at frontward and backward positions in a direction along a recording track. Namely, the laser beam at λ_1 = 443 nm was allowed to precede the laser beam at λ_2 = 780 nm in order to make scanning on the disk. The laser beam at λ_1 = 443

spot at the wavelength λ_2 precedes the laser spot at the wavelength λ_1.

In the sixth and seventh embodiment described above, recording and reproduction are performed by using the magneto-optical disk obtained in the second embodiment. However, it is also allowable to use the magneto-optical disk obtained in the third embodiment. When the magneto-optical disk obtained in the first embodiment is used, it is impossible to reproduce information on one of the magnetic layers by using only the reproducing light beam having one of the wavelengths. Accordingly, information on both of the layers is once reproduced by using the reproducing light beams having the wavelengths λ_1 and λ_2. Only information on one of the magnetic layers is stored, which is combined with information to be recorded on the other magnetic layer, followed by recording by using the recording light beam. Thus it is possible to execute a recording method in which only one of the layers is subjected to rewriting.

Eighth Embodiment

(Fourth Embodiment of Magneto-optical Recording Medium)

In the aforementioned embodiments, the rare earth metal-transition metal alloy comprising the same components (TeFeCo) has been used for the first and second magnetic layers. On the contrary, this embodiment exemplifies a magneto-optical recording medium produced by using

CLAIMS

1. A method for recording and reproduction on a magneto-optical recording medium including a plurality of magnetic layers (3,5), in which multi-valued information is recorded on the magneto-optical recording medium as a combination of magnetization states of the respective magnetic layers (3,5), and the multi-valued information is reproduced on the basis of an aggregate of the magnetization states of the respective magnetic layers (3,5), characterized in that:

the plurality of the magnetic layers (3,5) are irradiated with light beams having wavelengths λ_1 and λ_2 ($\lambda_2 \neq \lambda_1$) respectively, signals reproduced from reflected light beams having the respective wavelengths are converted into two-valued or higher multi-valued reproduction signals respectively, and then the converted reproduction signals concerning the respective wavelengths are mutually subjected to logical operation to reproduce the recorded multi-valued information.

2. The method for recording and reproduction on the magneto-optical recording medium according to claim 1, wherein the magneto-optical recording medium to be used is a magneto-optical recording medium in which a ratio of intensities of reproduction signals detected for a plurality of magnetization states determined by the

combination of the magnetization states, concerning the reproduction signals obtained at the wavelength λ_1, is mutually different from that concerning reproduction signals obtained at the wavelength λ_2.

3. The method for recording and reproduction on the magneto-optical recording medium according to claim 1 or 2, wherein the magneto-optical recording medium to be used is a magneto-optical recording medium in which an order of intensities of a plurality of reproduction signals detected for a plurality of magnetization states determined by the combination of the magnetization states, obtained upon detection at the wavelength λ_1, is mutually different from that obtained upon detection at the wavelength λ_2.

4. The method for recording and reproduction on the magneto-optical recording medium according to claim 3, wherein the magneto-optical recording medium to be used is a magneto-optical recording medium including two magnetic layers (3,5) capable of four-valued recording on the basis of four combined magnetization states, in which magnitudes of reproduction signals θ_1 to θ_4 from the four magnetization states, obtained upon reproduction at the wavelength λ_1, are different from those obtained upon reproduction at the wavelength λ_2, wherein:

the two magnetic layers (3,5) are irradiated with the light beams having the wavelengths λ_1 and λ_2 respectively,

signals reproduced from respective reflected light beams are sliced by using at least one level to obtain two-valued or higher multi-valued reproduction signals respectively, and the two-valued or higher multi-valued reproduction signals concerning the respective wavelengths are mutually subjected to logical operation to reproduce information recorded by four-valued recording.

5. A method for recording and reproduction on a magneto-optical recording medium including a plurality of s (3,5), in which multi-valued information or a plurality of two-valued information series are recorded on the magneto-optical recording medium as a combination of magnetization states of the respective magnetic layers (3,5), and the multi-valued information or the plurality of the two-valued information series are reproduced on the basis of an aggregate of the magnetization states of the respective magnetic layers (3,5), characterized in that:

the plurality of the magnetic layers (3,5) are irradiated with light beams having wavelengths λ_1 and λ_2 respectively, information recorded on one (3) of the magnetic layers (3,5) is reproduced via the combination of magnetization states of the respective magnetic layers (3,5) by using the light beam having the wavelength λ_1, information recorded on another (5) of the magnetic layers (3,5) is reproduced via the combination of magnetization states of the respective magnetic layers (3,5) by using the

light beam having the wavelength λ_2 ($\lambda_2 \neq \lambda_1$), and thus information is independently reproduced from each of the magnetic layers (3,5).

6. The method for recording and reproduction on the magneto-optical recording medium according to claim 5, wherein the magneto-optical recording medium to be used is a magneto-optical recording medium in which an order of intensities of a plurality of reproduction signals detected for a plurality of magnetization states determined by the combination of the magnetization states, obtained upon detection at the wavelength λ_1, is mutually different from that obtained upon detection at the wavelength λ_2.

7. The method for recording and reproduction on the magneto-optical recording medium according to claim 5 or 6, wherein information recorded on one (3) of the magnetic layers (3,5) is reproduced by radiating a light beam having the wavelength λ_1 or λ_2, while the reproduced information is combined with information to be recorded on another (5) of the magnetic layers (3,5) to perform recording by using a recording light beam having the wavelength λ_1 or λ_2, and thus only information on the another of the magnetic layers (3,5) is rewritten.

8. The method for recording and reproduction on the magneto-optical recording medium according to claim 7,

wherein the magneto-optical recording medium to be used is a magneto-optical recording medium including two magnetic layers (3,5) capable of four-valued recording on the basis of four combined magnetization states, in which an order of magnitudes of reproduction signals θ_1 to θ_4 from the four magnetization states, obtained upon detection at the wavelength λ_1, is different from that obtained upon detection at the wavelength λ_2, and wherein:

two-valued information on one (3) of the magnetic layers (3,5) is reproduced by using the light beam having the wavelengths λ_1, and two-valued information on the other magnetic layer (5) is reproduced by using the light beam having the wavelengths λ_2.

9. The method for recording and reproduction on the magneto-optical recording medium according to claim 8, wherein a two-valued signal converted into two-valued one by slicing, at a predetermined level, a reproduction signal including the four magnetization states detected at the wavelength λ_1 corresponds to a two-valued magnetization state of one (3) of the magnetic layers (3,5), and a two-valued signal converted into two-valued one by slicing, at a predetermined level, a reproduction signal including the four magnetization states detected at the wavelength λ_2 corresponds to a two-valued magnetization state of the other magnetic layer (5).

10. The method for recording and reproduction on the magneto-optical recording medium according to claim 7, wherein information is independently recordable on each of the magnetic layers (3,5), and information is independently reproducible from each of the magnetic layers (3,5) by selecting the wavelength of the light beam with which the magneto-optical recording medium is irradiated.

11. The method for recording and reproduction on the magneto-optical recording medium according to claim 1, wherein λ_1 is 350 to 900 nm, and λ_2 is a wavelength different from λ_1 by not less than 50 nm.

12. The method for recording and reproduction on the magneto-optical recording medium according to claim 5, wherein λ_1 is 350 to 900 nm, and λ_2 is a wavelength different from λ_1 by not less than 50 nm.

13. The method for recording and reproduction on the magneto-optical recording medium according to claim 1, wherein the magneto-optical recording medium is irradiated with the light beam at λ_1 and the light beam at λ_2 so that the two beams are collected at different portions on a recording area of the magneto-optical recording medium respectively.

14. The method for recording and reproduction on the

magneto-optical recording medium according to claim 5, wherein the magneto-optical recording medium is irradiated with the light beam at λ_1 and the light beam at λ_2 so that the two beams are collected at different portions on a recording area of the magneto-optical recording medium respectively.

15. A magneto-optical recording medium to be used for the method for recording and reproduction according to claim 1, including a plurality of magnetic layers (3,5) on a substrate, on which multi-valued information is recorded on the basis of a combination of magnetization states of the plurality of the magnetic layers (3,5), characterized in that:

a ratio of magnitudes of Kerr rotation angles read from a plurality of magnetization states determined by the combination of the magnetization states, obtained upon reproduction by using a light beam having a wavelength λ_1, is mutually different from that obtained upon reproduction by using a light beam having a wavelength λ_2.

16. The magneto-optical recording medium according to claim 15, wherein optical path lengths of layers for constructing the magneto-optical recording medium are adjusted so that the ratio of magnitudes of Kerr rotation angles read from a plurality of magnetization states determined by the combination of the magnetization states,

obtained upon reproduction by using the light beam having the wavelength λ_1, is mutually different from that obtained upon reproduction by using the light beam having the wavelength λ_2.

17. The magneto-optical recording medium according to claim 15 or 16, wherein a magnetic material for at least one magnetic layer (3) of the plurality of the magnetic layers (3,5) is selected so that the ratio of magnitudes of Kerr rotation angles read from a plurality of magnetization states determined by the combination of the magnetization states, obtained upon reproduction by using the light beam having the wavelength λ_1, is mutually different from that obtained upon reproduction by using the light beam having the wavelength λ_2.

18. The magneto-optical recording medium according to claim 17, wherein the magnetic material for at least one magnetic layer (3) is garnet.

19. A magneto-optical recording medium to be used for the method for recording and reproduction according to claim 5, including a plurality of magnetic layers (3,5) on a substrate, on which multi-valued information or a plurality of two-valued information series are recorded on the basis of a combination of magnetization states of the plurality of the magnetic layers (3,5), characterized in

that:

magnitudes of Kerr rotation angles read from a plurality of magnetization states determined by the combination of the magnetization states differ depending on a wavelength of a reproducing light beam respectively; and

the magneto-optical recording medium has a magneto-optical characteristic that a curve, which represents variation in the Kerr rotation angle with respect to the wavelength of the reproducing light beam detected from one combined magnetization state, intersects a curve which represents variation in the Kerr rotation angle with respect to the wavelength of the reproducing light beam detected from at least one of other combined magnetization states, in a wavelength range of λ_1 to λ_2 of the wavelength of the reproducing light beam.

20. The magneto-optical recording medium according to claim 19, further comprising at least one dielectric layer and comprising the plurality of the magnetic layers (3,5) on a substrate, wherein optical path lengths of the at least one dielectric layer and the plurality of the magnetic layers (3,5) are adjusted so that the magneto-optical recording medium has the magneto-optical characteristic that the curve, which represents variation in the Kerr rotation angle with respect to the wavelength of the reproducing light beam detected from one combined magnetization state, intersects the curve which represents

variation in the Kerr rotation angle with respect to the wavelength of the reproducing light beam detected from at least one of other combined magnetization states, in the wavelength range of λ_1 to λ_2 of the wavelength of the reproducing light beam.

21. The magneto-optical recording medium according to claim 19 or 20, wherein a magnetic material for at least one magnetic layer (3) of the plurality of the magnetic layers (3,5) is selected so that the magneto-optical recording medium has the magneto-optical characteristic that the curve, which represents variation in the Kerr rotation angle with respect to the wavelength of the reproducing light beam detected from one combined magnetization state, intersects the curve which represents variation in the Kerr rotation angle with respect to the wavelength of the reproducing light beam detected from at least one of other combined magnetization states, in the wavelength range of λ_1 to λ_2 of the wavelength of the reproducing light beam.

22. The magneto-optical recording medium according to claim 21, wherein the magnetic material for at least one magnetic layer (3) is garnet.

23. The magneto-optical recording medium according to claim 19, comprising at least a dielectric layer (2), first

and second magnetic layers (3,5), and an auxiliary magnetic layer (6) on the substrate, wherein at least one (3) of the first and second magnetic layers (3,5) is represented by the following general formula:

$$(Tb_{100-A}Q_A)_XFe_{100-X-Y-Z}Co_YM_Z$$

wherein:

15 atomic % ≤ X ≤ 40 atomic %;

5 atomic % ≤ Y ≤ 20 atomic %;

0 atomic % ≤ Z ≤ 15 atomic %;

0 atomic % ≤ A ≤ 30 atomic %;

wherein M is at least one of elements selected from the group consisting of Nb, Cr, Pt, Ti, and Al, and Q is at least one of elements selected from the group consisting of Gd, Nd, and Dy.